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SINTERING OF VLADIMIROVSKOE KAOLIN WITH HIGH-MELTING CLAY

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The possibility and the conditions for improving the sinterability of Vladimirovskoe kaolin by means of using high-melting variegated-color clay from the same deposit are considered.

Kaolins are commonly used in the production of aluminosilicate refractories. The chamotte products based on kaolin binder are hard to condense in molding and in firing [1, 2]. As a consequence, the porosity of fired articles is high. That is why the development of a method for increasing the density of the products made of kaolin material remains topical.

The present paper describes the problem of intensifying the sintering of kaolin from the Vladimirovskoe deposit (Ukraine) with the aim of applying the obtained results in the production of chamotte articles without using such a traditional additive as DN-2 clay from the Novoraiskoe deposit.

One of the factors which prevents sintering of articles based on Vladimirovskoe kaolin is the absence of a sufficient amount of oxides in its composition [3].

It order to solve this problem, it was proposed to add high-melting variegated-color clay with an elevated content of alkaline and alkaline-earth oxides. The chemical composition of the variegated clay is as follows (here and elsewhere, wt.%): 63.75 SiO_2, 20.16 Al_2O_3, 0.96 TiO_2, 3.34 Fe_2O_3, 1.26 CaO, 0.98 MgO, 0.55 Na_2O, 1.33 K_2O, 0.07 SO_3, 7.76 calcination loss.

The variegated clay is the stripping rock removed to the spoil heap in the extraction of kaolin from the specified deposit. The refractoriness of the average clay sample was 1480°C.

Based on the degree of contamination, this clay is regarded as having a high content of coarse-grained inclusions (8.7% fraction of size over 0.5 mm), but the size of inclusions is classified as small (the prevailing inclusion size is below 1 mm). The impurities in this clay are mostly represented by quartz, and the argillaceous component is represented by minerals of the kaolinite, montmorillonite, and hydromica groups. By the granular composition, this is a low-disperse material. The contents of the fractions below 10 μm is 72.3%, and the content of the fractions below 1 μm is 19.5%. The plasticity number of this clay is 19.6, which puts it in the medium-plasticity category of argillaceous materials.

In spite of the elevated content of alkaline and alkaline-earth oxides, the variegated clay is a non-sinterable argillaceous material. This is due to the high content of quartz sand (up to 18.8% fraction of size more than 0.1 mm). It was assumed that the use of variegated clay to intensify the sintering of Vladimirovskoe kaolin would not be effective without preliminary treatment. It was necessary to remove quartz sand from the clay and to determine the required degree of refinement.

The concentration of the variegated clay was carried out by passing the slip through sieves with holes of 0.63, 0.4, 0.2, and 0.063 mm. Next, the slip was dehydrated, and the concentrated clay was used to mold samples by plastic molding. The samples then were dried and fired in a silite furnace at various temperatures, and their properties were determined.

The properties of samples fired at temperature 1200°C after extracting different impurity fractions from the clay are indicated in Table 1. As the size and the content of extracted impurities grow, the sinterability of the variegated clay improves. This is demonstrated by increasing shrinkage, apparent density, and strength, and decreased water absorption of the fired samples. The minimum water absorption of the samples made of variegated clay before removing impurities

TABLE 1

Parameter	Extracted impurities fraction, mm				
	without extraction	> 0.63	> 0.4	> 0.2	> 0.06
Firing shrinkage, %	5.6	8.1	8.7	9.5	9.5
Water absorption, %	5.2	2.5	1.1	0.9	1.0
Apparent density, g/cm^3	2.29	2.38	2.43	2.46	2.48
Compressive strength, MPa	39.3	57.9	61.3	62.2	64.0

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TABLE 2

Parameter	Clay content, %	Firing temperature, °C						
		1100	1200	1300	1350	1400	1450	1500
Firing shrinkage, %	0	3.3	8.2	14.9	15.3	15.8	17.1	17.9
	15	4.2	9.8	12.4	13.4	14.1	14.2	14.5
	25	4.7	10.0	12.4	13.2	13.5	12.9	12.6
	35	5.6	10.4	11.5	11.9	12.2	10.9	10.2
Water absorption, %	0	34.9	23.3	11.6	10.0	8.2	5.5	2.4
	15	27.1	15.8	8.3	7.2	4.7	3.1	2.3
	25	22.5	11.0	5.3	4.1	3.2	2.9	3.6
	35	18.8	9.4	4.6	3.8	2.6	2.5	4.2
Apparent density, g/cm^3	0	1.40	1.67	2.01	2.13	2.20	2.30	2.33
	15	1.56	1.89	2.17	2.20	2.27	2.32	2.35
	25	1.68	2.07	2.24	2.27	2.31	2.32	2.27
	35	1.80	2.14	2.25	2.28	2.30	2.22	2.09
Compressive strength, MPa	0	13.5	25.0	40.8	50.0	53.0	63.9	72.7
	15	24.9	37.5	53.0	–	61.9	72.6	75.7
	25	30.0	45.0	59.0	–	63.5	63.9	64.0
	35	43.0	58.3	66.9	–	65.3	58.7	52.8

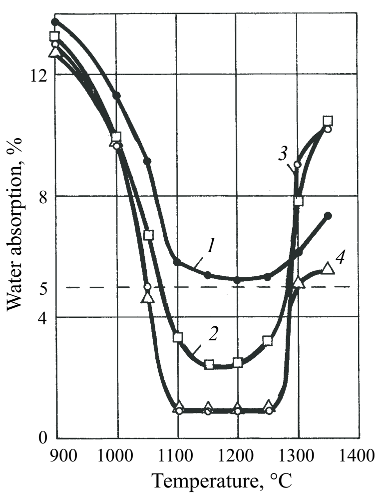

Fig. 1. Water absorption of samples depending on the firing temperature and the size of impurities extracted from variegated clay: *1*) without extraction, *2*, *3*, and *4*) extraction of fraction > 0.63, > 0.2, and > 0.063 mm, respectively.

is 5.2%. After the removal of impurities larger than 0.2 – 0.4 mm (in the amount of 14.0 – 10.6%), whereas the residual content of these impurities was 7.8 – 11.2%, the minimum water absorption of the samples dropped to 0.9 – 1.1% (Fig. 1). The removal of quartz particles larger than 0.2 – 0.4 mm from the variegated clay transformed this clay from non-sintering into a highly sinterable argillaceous material. A further decrease in the limiting size of extracted impurity grains makes no sense, as it does not substantially decrease the water absorption of fired samples, i.e., it has little effect on improving the sinterability of the variegated clay.

The studies considered the effect of the content of the variegated clay (0, 15, 25, and 35%) after impurities larger than 0.4 mm were removed, on the sintering of KV-1 kaolin. The clay and the kaolin were mixed in a porcelain ball mill. The samples were plastically molded and fired in a silite furnace within the temperature interval 1100 – 1500°C.

It was found that the sample properties are determined by the variegated clay content and the firing temperature (Table 2). For clay content in kaolin varying within the limits of 0 – 15%, condensation is observed in the samples up to the maximum firing temperature of 1500°C. With the clay content 25% or more, the temperature of the maximum condensation drops and is below 1500°C. After condensation, the material starts swelling: its shrinkage, apparent density, and compressive strength decrease. The higher the variegated clay content in the kaolin, the sooner (i.e., at a lower temperature) and the more intense is the swelling of the material.

It was interesting to determine the effect of the variegated clay content on the sample sintering temperature at which the water absorption of the sample is below 5%. The calculation indicated that mixtures of kaolin, chamotte, and variegated clay can have practical significance for binder sintering in chamotte products when the variegated clay content does not exceed 15%.

Based on the experimental data (Table 2), it was found that the sintering temperature of kaolin without additives is 1460°C. On adding 15% variegated clay to the kaolin, the sintering temperature of the mixture decreases by 65°C (1395°C).

As the variegated clay content in the kaolin grows, the starting temperature of swelling and the burn temperature decrease as well. Thus, kaolin without clay and with 15% clay starts swelling at a temperature above 1500°C. With 25% clay content in the mixture, the initial swelling temperature is 1500°C.

Thus, the use of mixtures of kaolin and variegated clay (or mixtures of kaolin, chamotte, and variegated clay) in production of refractories with a clay content up to 15% will not lead to swelling of the material before the firing temperature reaches 1500°C.

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